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Research Report

Water Scarcity and Managing Seasonal Water Crisis: Lessons from the Kirindi Oya Project in Sri Lanka

R. Sakthivadivel, Ronald Loeve, Upali A. Amarasinghe and Manju Hemakumara

International Water Management Institute

Research Reports

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Contents

Abbreviations and Acronyms

BS	Booting Stage
DCO	Distributary Channel Organization
EFC	Ellegala Feeder Canal
EIS	Ellegala Irrigation System
FMS	Flowering and Milking Stage
FO	Farmer Organization
GIS	Geographic Information System
GPS	Global Positioning System
ID	Irrigation Department
INMAS	Integrated Management of Major Irrigation Systems
IWMI	International Water Management Institute
KOISP	Kirindi Oya Irrigation and Settlement Project
LB	Left Bank
LHG	Low Humic Gley Soils
LP	Land Preparation
MOL	Minimum Operating Level
NIS	New Irrigation System
NS	Nursery Stage
OFCs	Other Field Crops
PMC	Project Management Committee
RB	Right Bank
RBE	Reddish Brown Soils
RWS	Rotational Water Supply
TS	Tillering Stage

Summary

Based on a case study of water management in the Kirindi Oya Irrigation and Settlement Project (KOISP) in southern Sri Lanka, this report describes the constraints in seasonal scheduling of water allocations from relatively small reservoirs that were not designed to carry storage from one season to the next. Predicting reservoir inflow is complicated because of annual variations in the beginning and end of the rainy season, as well as the amount of seasonal rainfall.

In the case of KOISP, irrigation scheduling is confounded by changes in the catchment that have resulted in periodic water scarcity. These changes have occurred since 1986 when the Lunugamwehera reservoir started operations and large-scale migration of settlers in the upstream catchment increased the local water demand. As a result, estimated average annual inflow into the reservoir started to decline. The problems are most acute during periods of low rainfall, for instance, during the 1992 *yala* (dry season from April to September) and the 1999 yala.

Crops failed completely during the 1992 yala, except in one part of KOISP served by a separate reservoir (Wirawila tank). This resulted from the fact that farmers had planted paddy in the entire Ellegala Irrigation System (EIS) in spite of warnings from the Irrigation Department (ID) that water levels in the reservoir were low. Reservoir inflow during the season was also lower than expected.

Stakeholder participation and farmers' acceptance of advice from the ID had improved much in the 1999 yala. This season's crop production was successful, although rainfall was much below average. This can be attributed to rotational operation of the system, but especially to greater cooperation from Distributary Channel Organization (DCO) leaders, ID staff and representatives of the farmer organizations (FOs). On the basis of the experience gained in the 1999 yala, members of the ID staff now argue that the yala inflow in years with water scarcity should not be taken into account when planning the yala cropping, but kept instead in reserve in the reservoir for a timely start of the following *maha* (wet season from April to September) cropping.

The farmers have learned to be more disciplined in their water use, and to value the reuse of drainage water, which was earlier not considered suitable for irrigation. It was found that farmers in the EIS, who have clayey or clay-loam soils may actually have higher yields in water-scarce years than in normal years. Further investigation is needed to determine the exact reason. Interestingly, most farmers who had high yields in the 1998 yala had even higher yields in the 1999 yala, although the average yields of 1999 were much lower than those of the previous year. Most farmers growing high-yielding varieties are located in the EIS. Farmers located in the Right Bank (RB) were especially affected by water scarcity at all stages of crop growth. Apparently, inequity in water distribution, due both to location within the system and to head-tail differences along canals, is exacerbated during dry years.

Water Scarcity and Managing Seasonal Water Crisis: Lessons from the Kirindi Oya Project in Sri Lanka

R. Sakthivadivel, Ronald Loeve, Upali A. Amarasinghe and Manju Hemakumara

Introduction

In the semiarid tropics, variation in annual rainfall is very high and the variation in monthly rainfall from year to year is even higher (Sanchez 1976). The onset and withdrawal of monsoon also vary from year to year making it difficult to predict reservoir inflow. Much of the rainfall is concentrated within 3 to 4 months of a year when a major part of the reservoir inflow takes place. Dry weather flow during the non-rainy season is considerably less with a high variability in flow. The uncertainties involved in predicting the quantum and timing of these rainfall and flow events make seasonal planing of irrigation scheduling cumbersome, especially when reservoirs are not designed and operated for carryover storage.

Two of the dominant factors used in seasonal planning are probable monthly or seasonal flow and the storage available at the time of planning. The long-term inflow data are used in estimating probable flow. However, in many irrigation systems, the long-term reservoir inflow and its pattern have drastically changed due to upstream watershed development caused by rapid demographic changes. Non-updating of the inflow data periodically to account for these changes leads to erroneous estimation of reservoir inflow, making seasonal planning uncertain. Short-term (monthly or fortnightly) forecasting procedures do not exist in most Asian irrigation systems, and even if they do, they are not updated to account for upstream changes, hindering the reliable estimation of reservoir flow.

On many occasions, for one reason or another, farmers do not follow the seasonal scheduling decisions that the Project Managers have taken and announced. Farmers also often violate these decisions by increasing the extent of irrigated area and/or changing the designated crops. Once farmers have planted a certain area with crops of their choice, then as per Irrigation Acts of many countries, it becomes obligatory on the part of the agency to provide water to all the planted area. This leads to inadequacy and change in the operational plan.

Coping with scarcity[1] of water supply for managing irrigation under uncertain and inadequate conditions has become part and parcel of many irrigation systems in the semiarid tropics of Asia. This situation has been created as explained above, by a change in hydrology of the catchment undergoing transitions, due to high variability of seasonal rainfall and improper estimation of reservoir inflow, and mainly due to stakeholders not adhering to rules and regulations put in place.

This report, through a case study of the Kirindi Oya Irrigation and Settlement Project (KOISP) in southern Sri Lanka, provides

[1]The word "scarcity" is used in the sense that the water supply is inadequate for the intended purpose at the time when it is needed.

evidence of the uncertain and inadequate inflow into the reservoir and its impact on the seasonal planning. The report is organized in two parts. Part I shows the uncertainty associated with estimated reservoir inflow and declining inflows to the reservoir leading to water scarcity at irrigation-system level. Part II shows coping mechanisms adopted under water-scarce conditions and their impact on the performance in the Kirindi Oya irrigation system. Water scarcity is illustrated by analyzing data from two dry seasons (1992 yala and 1999 yala).

The report also describes the processes and procedures that the ID adopted, in association with FOs, to overcome acute water shortage that occurred during the 1999 yala and how it was able to distribute the limited water supply during the season. An evaluation of these processes and procedures allows us to analyze how far the method adopted by the ID and the farmers has succeeded, where it has failed, and how this could have been improved to increase the productivity and production of the Kirindi Oya system. Such an evaluation provides not only an insight into the processes and procedures adopted to bring about a successful season but also guidance for managers operating systems under similar water-scarce conditions to improve their scheduling and operational plans. The results of the 1999 yala were compared with those of the 1998 yala, a year of normal water supply to the reservoir, to determine whether the seasonal operation was successful or not.

PART 1

Water Shortages in the KOISP

Introduction

The KOISP is located in the dry zone of the southeast quadrant of Sri Lanka (figure 1). The KOISP, an expansion of the old Ellegala Irrigation System (EIS), comprises the Lunugamwehera reservoir damming the Kirindi Oya river upstream of EIS and two main canals (Right Bank [RB] and Left Bank [LB]) irrigating about 5,340 hectares (13,560 acres), in addition to supplying water to the old EIS and the nearby Badagiriya system. Some salient features of the system are listed in table 1. The Lunugamwehera reservoir and the main canals were completed in 1986 and water issues were started from the 1986 yala.

Prior to 1991, seasonal allocation decisions in Kirindi Oya were generally made in a Project Management Committee (PMC) meeting[2] presided over by the Government Agent (GA).[3] Under the Integrated Management of Major Irrigation Systems (INMAS) program, farmers were grouped to form hydrologically based organizations. These organizations select farmer representatives who sit with officials from relevant agencies, including the ID, on joint management committees that make seasonal allocation decisions and resolve various problems. The top-level joint committee is the PMC and is chaired by the Project Manager from the Irrigation Management Division (IMD).[4] The INMAS advocates the establishment of a pyramidal committee structure operating on three tiers: FOs, DCOs, and the PMC. In the case of Kirindi Oya, a single PMC was constituted in 1990 by combining the PMCs of the old EIS and NIS. In light of participatory irrigation system management, PMC is the legitimate decision-making body for seasonal allocations.

Water Shortages

The water resources of the Kirindi Oya basin have been the subject of discussion since the project was initiated. The water availability in the basin during the planning stage was found to be overestimated by about 20 percent. A later study that IWMI conducted found that the Kirindi Oya irrigation system is indeed a water-short

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[2]PMC meeting: Meeting of farmer representatives and irrigation-related officials convened by the GA under the Irrigation Act of Sri Lanka.

[3]The GA is the chief development executive at district level.

[4]IMD is an arm of the Ministry of Irrigation and works in parallel with the ID, an agency under the Ministry of Irrigation. IMD was set up to facilitate input and services in major irrigation projects.

FIGURE 1.
Map of the study area: Kirindi oya irrigation and settlement project.

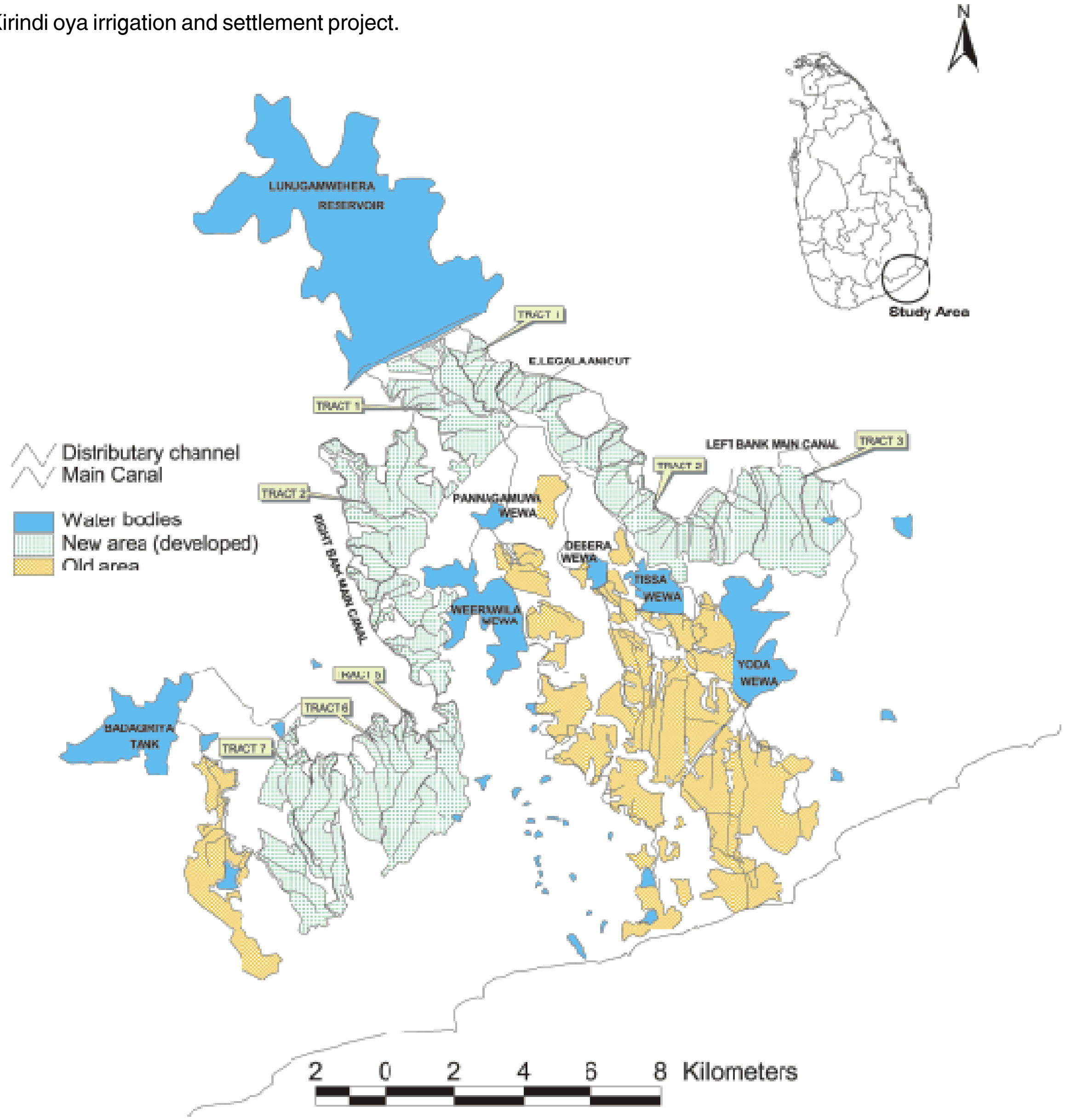


TABLE 1.
The KOISP system descriptors.

Descriptor	Value
Irrigable area	13,300 ha
Irrigated area	9,430 ha EIS–4,090 ha New Irrigation System (NIS)–5,340 ha
Annual rainfall	1,152 mm (maha: 810 mm; yala: 380 mm)
Reference crop potential evapotranspiration	2,000 mm
Method of water supply	Main storage reservoir Lunugamwehera (gross capacity 222 MCM; active capacity 198 MCM) Five medium old tanks (all interconnected)
Water delivery infrastructures	Gravity, with unlined primary, secondary and tertiary canals
Type of water distribution	Main canal running continuously and rotational water supply (RWS) in secondary and tertiary canals
Predominant on-farm irrigation practice	Surface irrigation with flooded basin
Major crops	Paddy, mainly with banana and vegetables as minor crops
Average farm size	1 ha of paddy land and ¼ ha of homestead
Type of soil	
EIS	Alluvial
NIS	Red brown earth (RBE) soils in upland Low humic gley (LHG) soils in lowland
Type of management	Main canals: ID Secondary canals: DCOs Tertiary canals: FOs Field level: Individual farmers

system (IIMI 1990), meaning that, on average, it does not receive the estimated design discharge in 3 out of 4 years.

Estimates of average annual flow into the Lunugamvehera reservoir show a decreasing trend over time (table 2). The opinion of the farmers and officials is that the inflow to the reservoir takes place only when rainfall is fairly high. Several factors may have contributed to this declining inflow, the main factor being the demographic and land use changes in the catchment upstream of the reservoir.

The Kirindi Oya catchment has undergone a rapid transition since the reservoir started operations in 1986. Large-scale migration of settlers to the upstream catchment was reported after 1986. It was observed during field visits that large-scale pumping from the river takes place in the upstream catchment, on either side of the river (estimated at around 2,000 pumps), to irrigate cash crops. More than 150 small reservoirs (tanks irrigating about 20 ha each) were repaired and rehabilitated for agricultural purposes since 1986. River water is also lifted for domestic purposes of the migrant settlers and the expanding towns nearby. All these activities may have had a marked effect on the inflow to the reservoir (table 2).

The objective of this part of the paper is to investigate whether there is any significant decrease in inflow to the reservoir due to upstream development, especially during the low rainfall periods.

TABLE 2.
Estimates of flow into the Lunugamwehera reservoir.

Year	Agency	Data Used	Average Inflow (MCM)	(ac. ft)	75 % Probable Inflow (MCM)	Remarks
1977	Asian Development Bank Appraisal (ADB 1977)	-	392	318,000	-	-
1986	Asian Development Bank Restudy (ADB 1986)	-	315	255,000	-	-
1994	ID in collaboration with IWMI (IWMI 1994)	1986–1992	290	235,000	181	Monthly data
2000	IWMI present study	1989–1999	279	226,000	166	Monthly data

Note: 1 hectare-meter (ha-m) = 8.1 acre-feet (ac.ft.), approximately.

Data and Methodology

Details of time series on water lifting or use in the upstream catchment are not available. Therefore, values of rainfall in the catchment along with values of inflows to the reservoir are used for this analysis. The monthly inflow data (from October 1989 to September 1999) are available from the IWMI database (figure 2) while continuous monthly rainfall data of only two stations in the catchment (Bandara Eliya Estate at 64° 7´ N and 81° .01´ E; and Ella (Kinnelan Estate) at 6° 52´ N and 81° .03´ E) were available at the Meteorological Department. We take the simple average of the two stations as the monthly catchment rainfall (figure 3). Though this may not accurately reflect the exact amount of rainfall in the catchment, it sufficiently indicates the trends of rainfall in the catchment for the study period.

Contribution from Rainfall to Trends of Inflow

To estimate the trends of inflow, the contribution of rainfall to the reservoir inflow has to be quantified first. Although the average rainfall of two stations may not give a sufficiently accurate estimate of average rainfall in the catchment, it may estimate the contribution to inflow due to variations in rainfall with sufficient accuracy. The inflow of a certain month could be related to the rainfall of that month and to the rainfall of the previous months (figure 4). The contribution of the previous month's rainfall on the current month inflow may either enter as the direct inflow (if the previous month's rain falls in the latter part of the previous month) or as the base flow (if the previous month's rain falls in the early part of the previous month). We estimated the effect of the rainfall of two successive months on the inflow to the reservoir.

Seasonal Effects

To uncover any trends after eliminating the effects of rainfall on reservoir inflow, we estimate any seasonal (monthly) variations left in the inflow series. For instance, the inflow of

FIGURE 2.
Monthly inflow, 1989 October–1999 September.

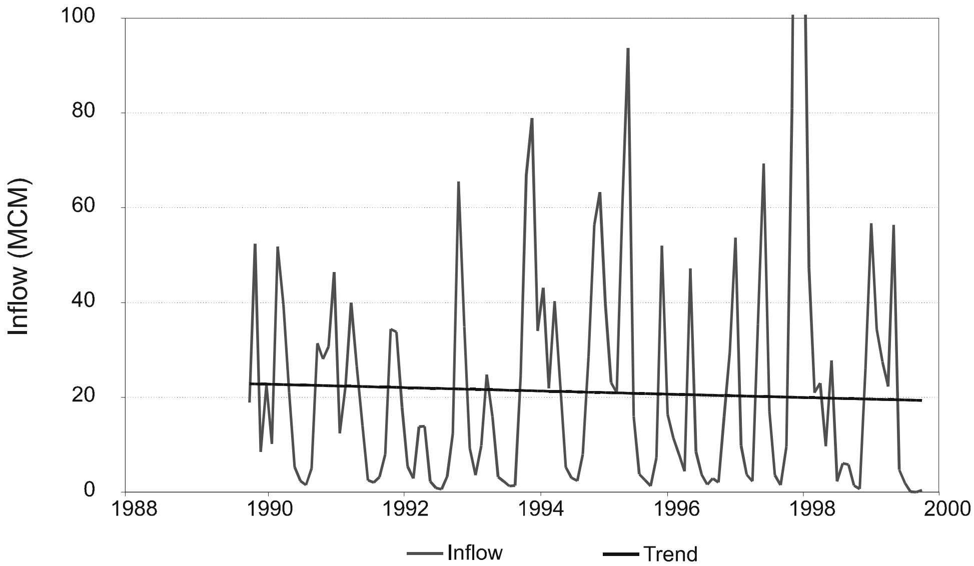


FIGURE 3.
Monthly rainfall, 1989 October–1999 September.

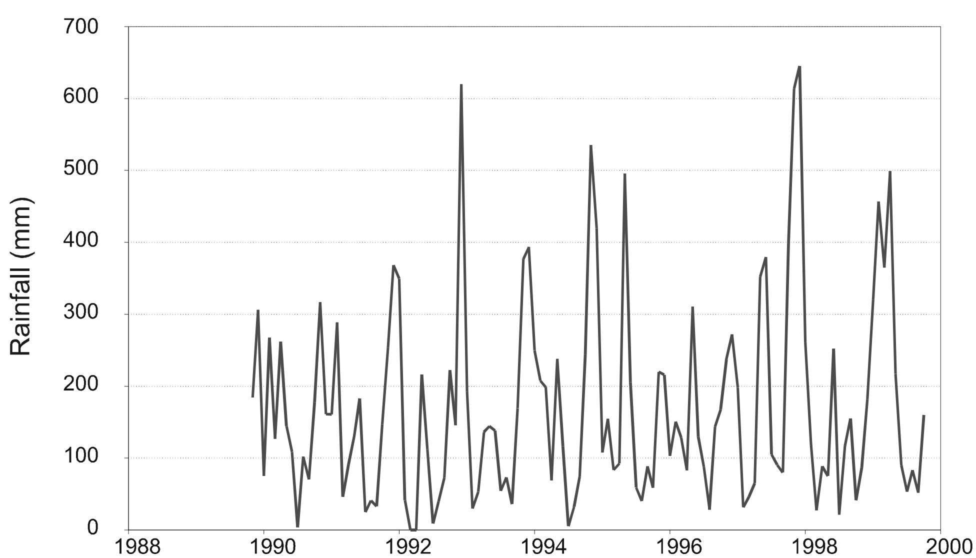
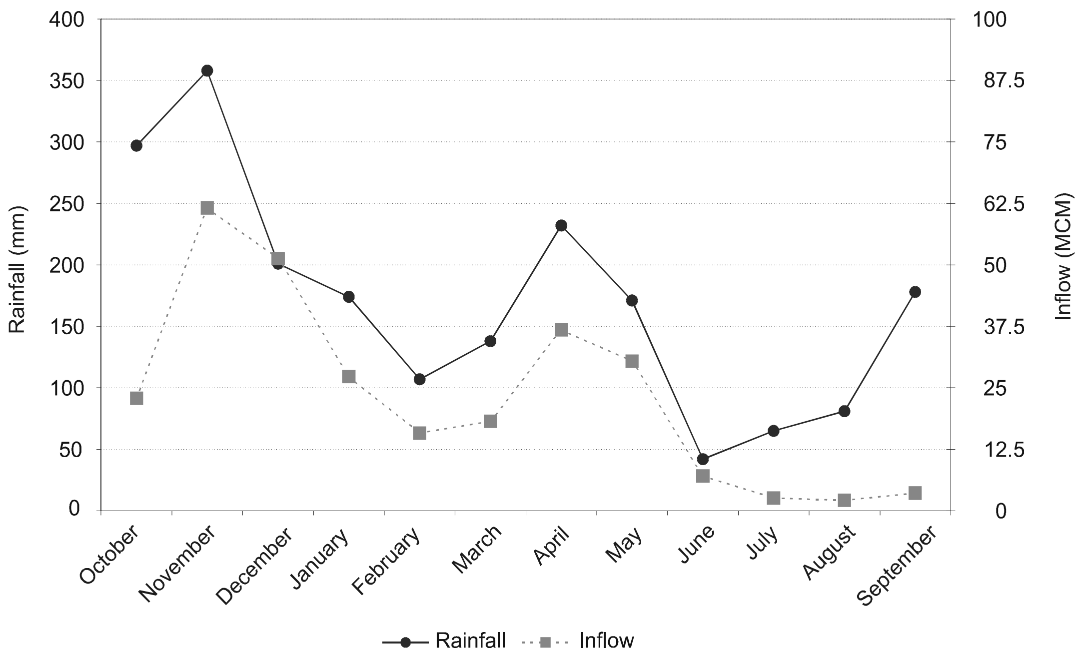


FIGURE 4.
Mean monthly rainfall in reservoir catchment and inflow to the reservoir.



some months may be higher or lower than others even after accounting for the effect of rainfall. We use dummy variables (i.e., = 1 for the particular month and = 0 for other months). For the monthly data we use 11 dummy variables for January through November and keep December as a baseline for comparison. Dummy variables for January through November show the variation of inflow compared to the month of December.

Trends of Inflow

We attribute any declining trend in reservoir inflow after extracting the effects of rainfall and seasonalities to the increased consumption in water use in the upstream catchment. Since the trend per month is expected to be small, we estimate only the trend per year. To represent the number of years for each observation from the beginning time period, we start the first month with 1/12 and add 1/12 to each succeeding month. Let,

$INFLOW_t$ = Inflow of the t^{th} month

RF_t = Rainfall of the t^{th} month

RF_{t-1} = Rainfall of the $(t-1)^{th}$ month,

JAN = Dummy variable of 0 and 1's, i.e., JAN = 1, if the month is January, and = 0 otherwise,

FEB = Dummy variable of 0 and 1's, i.e., FEB = 1, if the month is February, and = 0 otherwise,

Similarly, we define dummy variables MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, and NOV for March through November.

$TREND_t$ = Trend variable (We define TREND=1/12 in 1989 January,…TREND=11 in 1999 December)

Using the above variables, the regression equation is written as

$$\mathrm{INFLOW}_t = \beta_0 + \beta_1 \mathrm{RF}_t + \beta_2 \mathrm{RF}_{t-1} + \beta_3 \mathrm{JAN} + \beta_4 \mathrm{FEB} + \beta_5 \mathrm{MAR} + \beta_6 \mathrm{APR} + \beta_7 \mathrm{MAY} + \beta_8 \mathrm{JUN} + \beta_9 \mathrm{JUL} + \beta_{10} \mathrm{AUG} + \beta_{11} \mathrm{SEP} + \beta_{12} \mathrm{OCT}_t + \beta_{13} \mathrm{NOV}_t + \beta_{14} \mathrm{TREND}_t$$

The first three components on the right-hand side of the equation are the effect of rainfall, the next 11 dummy variables represent the additional monthly effects, and the last component is the annual trend. Estimates of the coefficients of the regression equation are given in table 3.

The constant term 22.2 is the predicted inflow at the beginning of the time period, after removing the seasonal effects. The rainfall values of the current month and the previous month are significant in explaining the variation of inflows to the reservoir.

In addition to the rainfall effects there are substantial variations between monthly inflows. For example, the monthly effects in November, January, March, April and May compared to December are not statistically significantly different. However, the effects of the deviations of yala months, especially in June, July, August and September are significantly lower compared to the effects in December.

Most importantly, the inflows, after filtering the effects of rainfall and seasonal effects, show a significant declining trend over the 10-year period (figure 2). From 1989 to 1999, there is, on average, an annual decline of 0.368 MCM of inflow to the reservoir.

TABLE 3.
Estimates of the coefficient of the regression equation.

Coefficient	Meaning	Estimate	t-statistic
Constant		22.2	3.0*
RF_t	Effect of t[th] month's rainfall	0.056	7.4*
RF_{t-1}	Effect of (t-1)[st] , previous month's rainfall	0.042	5.1*
JAN	Difference of January inflow from December inflow	-11.4	-1.5
FEB	Difference of February inflow from December inflow	-18.1	-2.3*
MAR	Difference of March inflow from December inflow	-14.7	-1.6
APR	Difference of April inflow from December inflow	-2.4	-0.3
MAY	Difference of May inflow from December inflow	-11.3	-1.3
JUN	Difference of June inflow from December inflow	-22.9	-3.2*
JUL	Difference of July inflow from December inflow	-23.1	-3.1*
AUG	Difference of August inflow from December inflow	-25.5	-3.5*
SEP	Difference of September inflow from December inflow	-30.1	-4.1*
OCT	Difference of October inflow from December inflow	-21.6	-2.8*
NOV	Difference of November inflow from December inflow	-3.2	-0.4
$TREND_t$	Trend of inflow	-0.368	-2.2*
	R^2	0.82	

* Statistically significant at 0.05 level.

Indeed, as observed in the field, there is a significant declining trend of inflow to the reservoir. However, the inflow has declined slowly over the 10-year period. The slow decreasing rate would suggest that this is a major problem only in months of low rainfall. If the rainfall is low, then in these months, little or no inflow would have entered the reservoir. Such situations in Kirindi Oya have, in fact, occurred in the 1992 and 1999 yala seasons (table 4). The inflows to the reservoir during part of the seasons were so low that the Kirindi Oya system had experienced a severe water-deficit situation.

In the 1992 yala, the reservoir received only 35 MCM of inflow against an average of 83 MCM. In the last four months (June to September) of the 1992 yala, inflow was only 7.1 MCM. The inflow during the same period in 1999 was only 2.4 MCM. However, the total values of rainfall of these months in the 2 years are more or less the same (342 mm in 1992 and 347 mm in 1999). In fact, there was no inflow to the reservoir in August 1999. During the 1999 yala the reservoir received only 63.5 MCM against an average of 83 MCM.

The severe impact of reservoir inflow during dry months of a water-scarce year has impact on the seasonal decision-making process of both farmers and agency officials in completely different ways. While the agency officials were very conservative in restricting the paddy cultivated area in a scarce year, the farmers did not understand the rationale for curtailment of paddy irrigated area and irrigated more area than what was decided at the PMC meeting, exacerbating the water-stress situation. Our focus in Part II is the coping mechanism of the agency officials and farmers in alleviating the negative impact of the water-stress situation in these seasons.

TABLE 4.
Rainfall and reservoir inflow of maha and yala seasons: 1989–1999 average, 1991–1992, 1997–1998 and 1998–1999.

Season	Month	Average 1989–1999 Rainfall mm	Inflow MCM	1991–1992 Rainfall mm	Inflow MCM	1997–1998 Rainfall mm	Inflow MCM	1998–1999 Rainfall mm	Inflow MCM
Maha	October	297	22.9	253	8.0	614	81.0	87	0.7
	November	358	61.6	368	34.4	645	204.4	181	26.1
	December	201	51.3	349	33.8	261	135.7	320	56.7
	January	174	27.3	41	17.9	118	47.3	456	34.4
	February	107	15.8	0	5.4	27	21	365	27.5
	March	138	18.2	0	2.9	89	23	499	22.3
	Total	1,275	197.1	1,012	102.4	1,754	512.4	1,909	167.7
Yala	April	232	36.8	216	13.8	75	9.7	217	56.4
	May	171	30.4	112	13.9	252	27.8	90	4.7
	June	42	7.1	9	2.3	21	2.3	53	1.9
	July	65	2.6	39	0.9	117	6.1	83	0.1
	August	81	2.1	72	0.6	155	5.8	51	0.0
	September	178	3.6	222	3.3	41	1.4	160	0.4
	Total	769	82.6	672	34.8	662	53.1	655	63.5
Annual total		2,044	280	1,684	137	2,416	566	2,564	231
Reservoir storage at beginning of yala			103.6		37.5		192.3		101.8

Part II

Water Scarcities and Agricultural Performance

Introduction

Two factors, the probable monthly flow and the storage at the time of planning, are dominant in seasonal planning. Smaller actual inflows during the season than expected at the planning stage lead to inadequate water situations. Moreover, the deviations of cropping patterns from the schedule that was agreed at the planning stage exacerbate the water-shortage situation. The 1992 yala and the 1999 yala at the KOISP are typical examples of the above situations. In this part we investigate the coping mechanisms that were adopted by farmers and agency officials in KOISP to mitigate the water-scarce situations and their impact on the agricultural performance. We start Part II with a brief description of water allocation decisions in the KIOSP. In the following sections, we describe data collection procedure, and water scarcities and agricultural performance in the 1992 yala and 1999 yala.

Water-Allocation Decisions

From the start of the KOISP in 1986 and until 1990, the old EIS and the NIS were managed as two separate entities by the ID without much consultation and communication between and among the stakeholders. After the formation of a single PMC in 1990, the ID, with the assistance of IWMI (then called IIMI) prepared seasonal operational plans for both maha and yala, taking into account the storage in the Lunugamwehera reservoir and the five EIS tanks at the time of planning (generally November 1), the expected 75 percent probable inflow to the reservoir and the zoning of the NIS with a priority order to receive water and start the maha cultivation in a staged manner (IWMI 1994).

This zoning procedure was necessary because of the inadequate water inflow to the Lunugamwehera reservoir. In view of the riparian right of the EIS it has the first priority to receive water in each season. The NIS was divided into 3 zones with LB tracts 1, 2 and 3 as zone 1, RB tracts 1 and 2 as zone 2 and RB tracts 5, 6 and 7 as zone 3 (figure 1), each having approximately 1,800 hectares (4,500 acres) and their priority to receive water in each season was rotated in a cyclic order. If zone 1 has the priority to receive water during maha, followed by zones 2 and 3, then in yala, zone 2 will have the first priority followed by zones 3 and 1, respectively, in that order.

The procedure followed for water release from the reservoir during maha is briefly as follows:

- The volume of water stored between the sill level (+150.0) and the minimum operating level (MOL) (+155.0) is reserved as the drinking water supply for the new settlers.

- If the storage volume above MOL is less than 1,852 hectare-meters (ha-m) (15,000 ac. ft.), then no water is released for irrigation for any command.

- If the storage is greater than 1,852 ha-m (15,000 ac. ft.) but less than 3,704 ha-m. (30,000 ac. ft.), then water is released only to the EIS for land preparation.

- If the storage is greater than 3,704 ha-m (30,000 ac. ft.), then for every additional 5,000 ac. ft. one tract in the new area is supplied with water and the tract selected for receiving water is as per priority order discussed previously.

The rationale for this kind of staged release of water during maha is to avert the problem of shortage, if any, and at the same time to capture the rainfall to the maximum extent possible. The extent of area thrown open for maha cultivation is based on a simple rule of thumb that an area to be irrigated with paddy during maha needs 1,950 to 2,100 mm (6.5 to 7.0 ac. ft./acre) as reservoir sluice discharge.

During yala, the planning is based on the water left over in the reservoir at the end of the maha and the expected inflow during the yala. The same criteria as used for maha (6.5 to 7.0 ac. ft./acre) are also used for yala to determine the extent of area, and the above-mentioned priority order is used to identify the tracts to be irrigated in yala.

The ID proposes the planning schedule and then the PMC discusses it at length to decide on the area to be thrown open for irrigation, date for completing maintenance activities by the DCOs and start and end dates of water release and completion date for land preparation. Also, each month during the season, the PMC meets to take stock of the water supply situation for the remaining period of the season. With the help of distributary channel farmer leaders, the ID implements the PMC-approved planning schedule.

Over the last 10 years of operation, two important changes have taken place. One is with respect to the cropping pattern. Farmers have become accustomed to growing paddy during both maha and yala. Raising paddy in both seasons has resulted in a serious problem for the long-term performance of the system in that growing paddy during yala leaves very little water in the reservoir to start the maha cultivation in time and to the full extent and vice versa. The old areas are the priority areas to receive water and will irrigate every maha; on the other hand, new area tracts may receive water along with the old area only when the reservoir inflow is sufficient enough. In some years, some of the tracts of the new area did not receive water even during maha. The paddy-growing culture has had a great impact on the underdevelopment of the new area, exacerbated by the dwindling flow to the reservoir, especially during yala. There is a kind of mindset among farmers of Kirindi Oya that irrigated agriculture means growing paddy. Even the banana cultivation that was given a push by the agency and the lending banks did not pick up very much. Banana cultivation has got stabilized at about 480 hectares (1,200 acres) in the NIS. Also cultivation of other field crops (OFCs) like vegetables is limited to certain pockets in the LB tracts of NIS where farmers are specializing in vegetable cultivation.

The other change is with respect to the operation of main canals and distributary channels during the crop-growing period. Prior to the 1998 yala, the main canal was operated continuously and distributaries were closed and opened according to the needs as perceived by farmers and sometimes discharges were adjusted based on the decision of gate operators, leading to inequity problems. Starting with the 1999 yala, two alternatives were made in the operational schedule. The first alternatives is with respect to the operations of the main canal and distribution channels; both the main canal and distributary channels were operated in an "on" and "off" mode with farmers knowing in advance the rotation pattern to overcome the head-tail inequity problems. This has made a marked change in the distribution of water within and between the field channels. While the above-mentioned planning procedure is generally adopted during the normal and wet years, the procedure adopted for water distribution in a water-scarce or drought year, especially when the drought sets in after farmers have planted their fields, is different. In such water-scarce years, the second alternative of delivering available water is adopted where the supply can be stretched up to the end of crop maturity.

Data-Collection Procedure

Several steps were adopted for collecting the requisite data for this study. Reservoir outflow data and meteorological data were collected from the ID. The drainage data of the command area and time series of monthly inflow data to the Lunugamwehera reservoir were obtained from the IWMI database. The minutes of the PMCs were perused to find out the decisions made at different stages of planning during and before the crop-growing season. The authors undertook a number of field visits to discuss matters with farmers, DCO leaders and agencies involved in operating and managing the system. Additional information required to answer specific questions was ascertained through a questionnaire, which was pre-tested and refined. Altogether 157 sample farmers were selected for the study. The coordinates of selected farmers' fields were determined using the GPS and the sampled field plots were plotted in a GIS map to analyze the yield data. The farmers' answers to the questionnaire were analyzed and the results of farmers' perceptions and their views were discussed with the system-operating agency to authenticate the veracity of farmers' responses.

Water Scarcity, 1992 Yala

The year 1992 was a drought year. The Lunugamwehera reservoir received only 137 MCM of water against an average inflow of 280 MCM. The dry period started in the latter part of the 1991/92 maha and continued during the 1992 yala with less rainfall in January and February. As a result, at the end of the 1991/92 maha all the tanks except Wirawila in the EIS were empty (see figure 1). The water level in the Lunugamwehera reservoir at the beginning of March was +162.5 (against the MOL of +155) with a storage of 19 MCM (15,420 ac. ft.), which was just sufficient to irrigate the standing maha paddy crop in the RB and OFCs in LB tract 3. In view of these situations and the unlikely event of receiving sufficient inflow, the ID warned the EIS farmers that water might not be sufficient for cultivating a yala paddy crop in the whole of EIS. However, despite the warnings of irrigation officials, the EIS farmers planted the whole area with paddy due to a lack of understanding of the importance of the MOL and the use of water below the MOL, mistrust of irrigation officials, and a desire to establish a right for yala water to irrigate the whole of EIS with paddy.

The ID was compelled to issue water from 1 May 1992 although the reservoir had only a limited volume of water. The inflow to the reservoir in yala (35 MCM against the expected 83 MCM) was not sufficient to cater to the needs of all the old areas. The farmers, with the approval of local political leaders, used a portion of water stored below MOL that was earmarked as the drinking water supply, for irrigation to tide over the crisis. Yet, they fell short of the required volume of water and, in spite of all their efforts, the 1992 yala was a season of complete crop failure except for the Wirawila tank command, which had the benefit of receiving drainage water from tracts 2 and 5 of the NIS from the previous season.

The dramatic event of the 1992 yala taught important lessons to farmers. At the beginning of the season, the EIS farmers distrusted the data on water availability that the ID provided. The distrust was caused in part by the failure of ID officials to explain the working of the reservoir and, especially, the significance of the MOL. The attempts to get more water during the season taught farmers a great deal about reservoir operations. By the end of the season, most EIS farmers understood the significance of the MOL for seasonal water allocations.

The Ellegala farmers learned it was not wise to disregard the ID warnings as counseled by some of their leaders. The 1992 yala event brings out the importance of rapport, understanding and trust among farmers and agencies managing the system for making a successful season.

Water Scarcity, 1999 Yala

The water availability at the beginning of the 1999 yala and monthly reservoir inflow given in table 4 indicate the severity of the situation where the availability of the water supply for the 1999 yala (102 MCM) is concerned. In view of the limited water supply and low storage at the beginning of the season, the PMC took a decision to cultivate 70 percent of the NIS command area with paddy and the remaining 30 percent with OFCs. Although the farmer representatives agreed to this decision at the PMC meeting, without heeding to the PMC decision the farmers went ahead and planted 100 percent of the area with paddy. This created a crisis of water inadequacy for the 1999 yala. Also, the expected inflow into the reservoir did not materialize causing further confusion in changing the scheduling already formulated. The unexpected action of farmers impelled the farmer representatives and the Irrigation Managers to consult each other to arrive at an operational plan for the best use of the limited water supply available in the reservoir. The plan arrived at and implemented was as follows:

- During the land preparation period, the main canal was run continuously at full supply discharge and all distributaries were supplied with water to complete land preparation in as short a time as possible. Considerable cooperation and help obtained from DCO leaders and FO representatives made this possible.

- After broadcasting paddy, farmers used to flood and drain their fields alternately two or three times to protect sprouting broadcasted paddy plants from submersion and to overcome the submersion effect of heavy rains likely to occur during this period. Generally, this process takes about a month. During the water-scarce 1999 yala the period of flushing and draining was restricted to 15 days only.

- Subsequent to this, rotational water supply in both the main canal and the distributary channels was started in an "on" and "off" mode. To determine the days of rotation, the agency computed the total number of days that all main canals could run at full supply discharge with the available storage and expected inflow into the reservoir. The number of weeks that water had to be supplied being known, the number of days in a week that the main canals would run at full supply was worked out and the canals were operated accordingly.

- The number of days that the main canals could run at full supply discharge was reviewed periodically by the PMC and adjustments were made to the number of days of canal running in a week to stretch the water supply to the end of the season.

- The DCO leaders and FO representatives took responsibility for the distribution of the water received at the distributary head to different field channels and within the field-channel command area.

Analysis of Water-Supply Distribution

The main- canal water issues for the RB, LB and Ellegala Feeder Canal (EFC) for the normal 1998 yala and the 1999 water-scarce yala are shown in figure 5. The total water issued is presented in table 5. In figure 5, the X-axis represents the days since the start of the season and the Y-axis represents the volume of water released per day in MCM. A comparison of the distribution indicates the following:

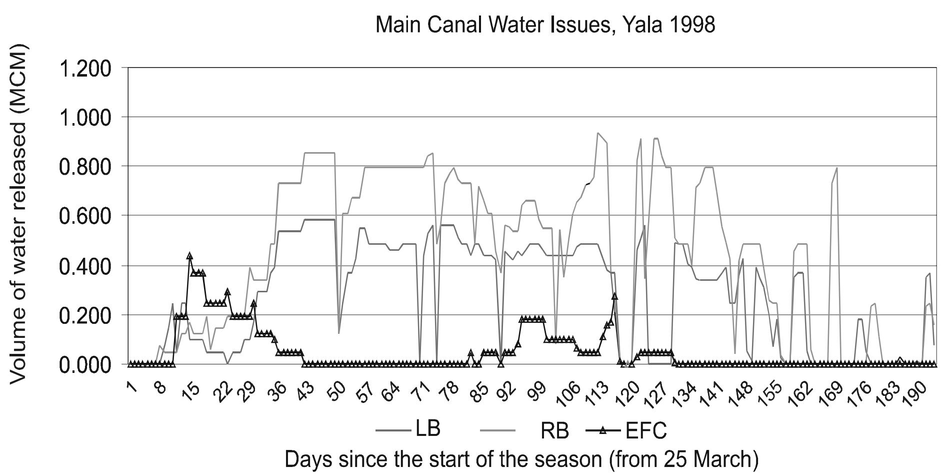
1 In the 1998 yala, water was supplied to the main canals for almost 6 months while in the 1999 yala it was restricted to only 5 months. Shortening the water-release period from 6 months to 5 months was an attempt to save water.

2 The water supply to the RB and LB canals was more or less continuous during the 1998 yala while in the 1999 yala, rotational water supply was introduced after the land preparation and nursery stages. During the rotation, the daily supply to the RB canal was gradually increased from 0.82 MCM to 1.1 MCM per day while the LB canal supply was kept constant except during the end of the crop-growth season. Water supply to the RB during the period of flowering and milking stage (100 to 120 days after the issue of water) was very much below par and fluctuating compared to the other periods that had affected the RB canal yield to a considerable extent.

3 The average volume of water supplied per day during the 1998 yala was approximately 0.8 MCM (less than full supply discharge) while in the 1999 yala, it was approximately 1.0 MCM, which was nearly the full supply discharge of the RB canal. The case of the LB canal is similar.

4 The EFC was supplied with water in an intermittent fashion in both the seasons. While the RB and LB canals received less water supply during the 1999 yala compared to the 1998 yala, the EFC received more supply during the 1999 yala (table 5). The reason for this increased supply to the EFC is that the quantum of drainage flow, which the old tanks should receive from RB and LB tracts, did not materialize during the 1999 yala (table 6).

FIGURE 5.
Water issues for RB, LB and EFC in the 1998 yala and 1999 yala.



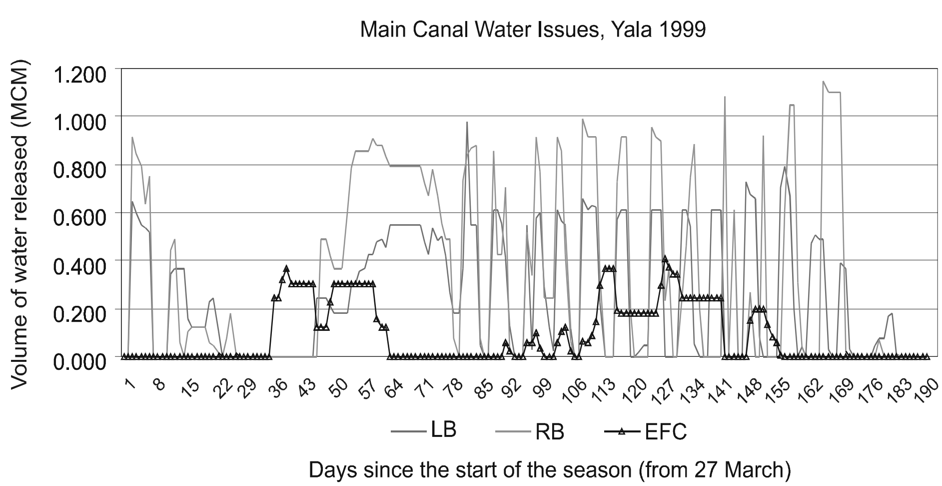


TABLE 5.
Comparison of water issues during the 1998 yala and the 1999 yala.

	Area (ha)	Total Issues (MCM)		Total Issues (mm)	
		1998	1999	1998	1999
New Area					
LB area	1,943	52.542	39.996	2,704	2,058
RB area	3,273	84.022	57.320	2,567	1,751
Feeder Canal Diversion	4,194	9.455	16.533	225	394
Old Area					
Weerawila	931	22.993	29.249	2,469	3,141
Debarawewa	405	6.599	6.580	1,630	1,625
Tissawewa	1,113	7.983	10.843	717	974
Yodawewa	1,336	19.373	10.518	1,450	787
Pannegamuwa	226	No data	No data	No data	No data

Note: The Debarawewa tank releases for 1999 as shown are estimated, as nearly 60 days of data are missing.

TABLE 6.
Drainage flow.

System	Drainage Flow (MCM)		Reduction (%)
	1998	1999	
Old system	20.75	13.11	37.0
RB tract 5	13.31	5.84	56.0

From the above observations and analysis, the following can be inferred from the water distribution and operation of the main canal distribution system in the KOISP.

- The main objective of the ID during the 1999 yala was to extend the limited water supply to the end of the crop-growing season to help mature the crops. It was able to achieve this by limiting the water supply to the canal to 5 months instead of the normal 6 months and introducing rotational water supply during the crop-growing period and operating the canal at full supply discharge.

- The major deficiency in the ID's planning was in estimating the total inflow available for distribution. The expected inflow during yala did not materialize resulting in reduced number of days of supply as well as the impossibility of operating the main canal at full supply discharge throughout the rotation period resulting in a head-tail inequity.

- Had the ID foreseen this shortfall in supply at a very early stage of the crop-growing period, it would have changed the operational plan. With the present operational practice, the crops in the RB and LB tail-end tracts were stressed to a considerable extent during the critical crop-growth stages, thereby drastically reducing the yield.

- The intermittent irrigation introduced during the 1999 yala had the following positive impacts:

- Farmers in the old Ellegala system who have clayey and clay-loam soils got higher yields than in normal years (see next section). Further investigation is needed to determine the exact reason. The season had almost clear days all through with good sunshine and no pest attack.

- The drainage flow to the sea from both the EIS and tract 5 has been considerably reduced due to rotational water supply (table 6).

- Farmers became more disciplined in receiving water and using it efficiently due to the higher management effort of the DCO leaders and field channel representatives.

- The reuse of drainage water has considerably increased; farmers have cross-bunded drainage channels at convenient places and diverted the drainage water to their fields either by gravity or by pumping.

- Until recently, farmers were of the opinion that drainage water was not good for reuse and were not using the drainage water. The water scarcity during the 1999 yala has forced them to reuse drainage water, which has now been accepted by the farmers and is being practiced in the 2000 yala.

The ID has also learnt a number of lessons:

- It has learnt how to manage a system during a water crisis. Now it is careful in estimating the yala inflow; in fact, the ID argues that the yala inflow in water-scarce years should not be taken into account for planning the yala crops and cropping pattern; instead it should be used as a reserve storage for starting the following maha cultivation in time and the maha rainfall can be effectively used.

- The ID claims that the successful completion of the 1999 yala is mainly due to three factors:

  - Cooperation received from the DCO leaders, FO representatives and lower-level ID field staff.

  - The simultaneous operation of the main canal and the distribution channels in an “on” and “off” mode.

  - Due to adverse criticism raised in the public media, the ID felt challenged to make the season a success and has put in a large management effort in coordinating the activities of the various stakeholders.

Analysis and Results of the Questionnaire Survey

A sample of 157 farmers was surveyed from the KOISP area to assess the changes in performance due to changes in water-delivery strategies under water-scarce conditions. Table 7 gives the breakdown of the surveyed farmers according to the schemes, location with respect to the field channel, tenure system and soil type of the farm.

TABLE 7.
Breakdown of the surveyed farmers according to the schemes, location with respect to the field channel, tenure system and soil type of the farm.

General information	Composition (number and percent[1]) of sample farmers			
	LB	RB	Old EIS	Total
Total number of farmers	31	50	76	157
Location with respect to the field channel				
Head	6 (19%)	21 (42%)	24 (32%)	51 (33%)
Middle	13 (42%)	12 (24%)	24 (32%)	49 (31%)
Tail	12 (39%)	17 (34%)	28 (36%)	57 (36%)
Tenure system				
Owner	26 (84%)	48 (96%)	31 (41%)	105 (67%)
Lessee	5 (16%)	2 (4%)	10 (13%)	17 (11%)
Tenant	0	0	35 (46%)	35 (22%)
Soil type				
Can retain standing water	21 (68%)	28 (56%)	60 (79%)	109 (69%)
Cannot retain standing water	10 (32%)	22 (44%)	16 (21%)	48 (31%)

[1]Percentage is with respect to the system total.

Water Delivery: Farmers' Perception

Almost all the sampled farmers were aware of the decisions taken at the PMC meetings on the water delivery schedule (table 8). It is estimated that the LB and RB farmers have experienced significant delays in water delivery from the agreed date of water delivery. It was also observed that the nonowner farmers have reported a significantly higher delay in the starting date of water delivery than the owners.

Mode of Water Delivery

Almost all farmers in KOISP are estimated to have received continuous water supply during the land preparation stage (table 8). In the subsequent stages, the number of farmers receiving continuous water supply is estimated to have decreased, from 60 percent in the nursery stage (NS) to 16 percent in the flowering and milking stage (FMS). Almost all farms in the LB and RB had rotational water supply after the nursery stage. One-third of the farmers in EIS received continuous supply even in the FMS stage.

Number of Dry Days in a Rotation

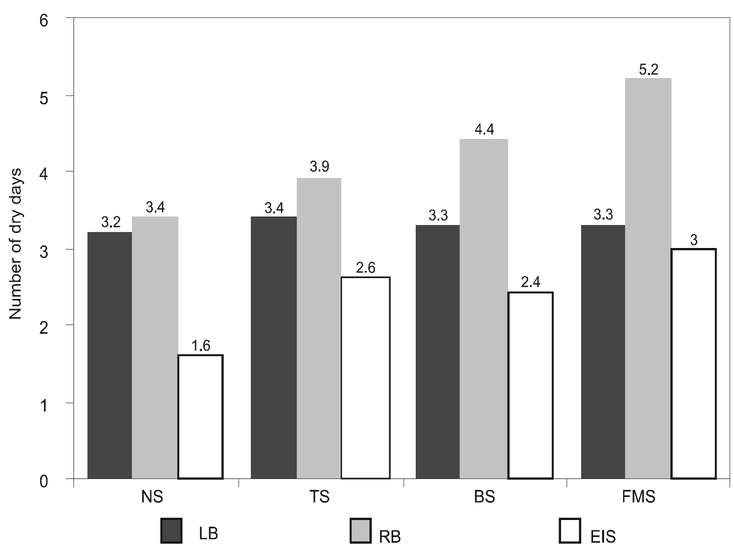
The average number of dry days in a rotation is highest in the RB and is lowest in the EIS. The average number of dry days at the RB has increased from 3.4 days in the NS to 5.2 days in the FMS (figure 6). Increasing number of dry days in the rotational schedule is reflected in the farmers' responses on water adequacy.

TABLE 8.
Farmers' knowledge of water delivery.

Factor	Distribution among Systems			
	LB	RB	EIS	KOISP
Farmers' knowledge on the PMC decision on the water delivery schedule (%)	94	86	93	91
Delay in water delivery (average number of days between agreed and actual water delivery)	14	9	0	6
Continuous mode of water supply				
- LP stage (%)	100	92	100	97
- NS stage (%)	35	32	89	60
- TS stage (%)	6	6	51	28
- BS stage (%)	6	0	37	19
- FMS stage (%)	3	0	31	16

LP=Land preparation; NS=Nursery stage; TS=Tillering stage; BS=Booting stage; FMS = Flowering and milking stage.

FIGURE 6.
Number of dry days in a rotation at NS, TS, BS and FMS.



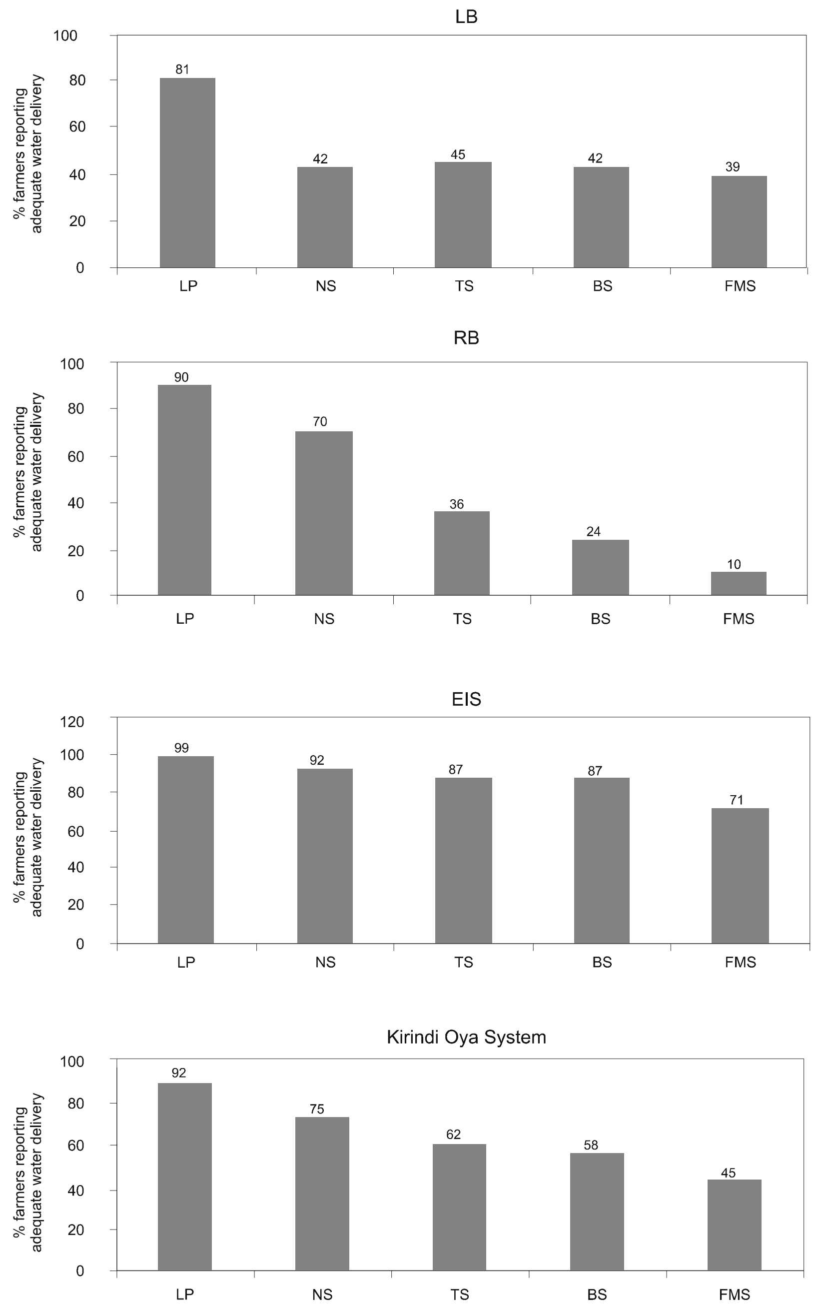
Note: NS, TS, BS, and FMS are as in table 8. LB= Left Bank; RB = Right Bank; EIS = Ellegala Irrigation System.

Perception on Water Adequacy

It was estimated that the majority of the farmers (92%) in all three systems have reported receiving an adequate volume of water during the land preparation stage (figure 7).

Most of the farmers in the old EIS have reported receiving adequate water deliveries in all stages (maximum of 92% in the NS to a minimum of 71% in the FMS). However, a different picture emerges in the LB and RB with the start of the rotational water supply. Only

FIGURE 7.
Farmers' perception on adequacy of water delivery at different stages.



Note: LP = Land preparation; NS = Nursery stage; TS = Tillering stage; BS = Booting stage; FMS = Flowering and milking stage; LB= Left Bank; RB = Right Bank; EIS = Ellegala Irrigation System.

about 40 percent of the farmers in the LB have reported receiving an adequate water delivery since the land-preparation stage. In the RB, the number of farmers who had received an adequate supply decreased rapidly from 70 percent in the NS to only 10 percent in the FMS.

Farmers have reported several negative effects due to water delivery inadequacies such as their inability to apply fertilizer, weedicide and pesticide in time, stunted plant growth, insufficient tillering and bearing of unfertile panicles. All these factors may have direct negative effect on the paddy yield.

Paddy Yield

Variation in the Paddy Yield

There is a substantial variation in the paddy yields (standard deviation of 3.4 tons/ha) in the KIOSP area in the 1999 yala. The average paddy yield in the KOISP is 4.0 tons/ha; more than 50 percent of the farmers have reported yields less than 3.75 tons/ha.

The average yield in the 1999 yala was significantly lower than that in the 1998 yala (figure 8). However, it is interesting to note that most farmers producing high-yielding varieties in 1998 have obtained even higher yields in the 1999 yala, the majority of them located in the old EIS. Table 9 shows the distribution of farmers according to the four quartiles of the 1999 yala paddy yields.

The majority of the farmers (97%) whose 1999 yields are in the fourth quartile (greater than 6.0 tons/ha) were from the old EIS. More than 81 percent of the farmers, whose 1999 paddy yields are in the upper quartile, have reported lower yields in 1998. Seventy percent of the farmers whose 1999 paddy yields are in the third quartile (between 3.75 and 6.0 tons/ha), have reported lower yields in 1998.

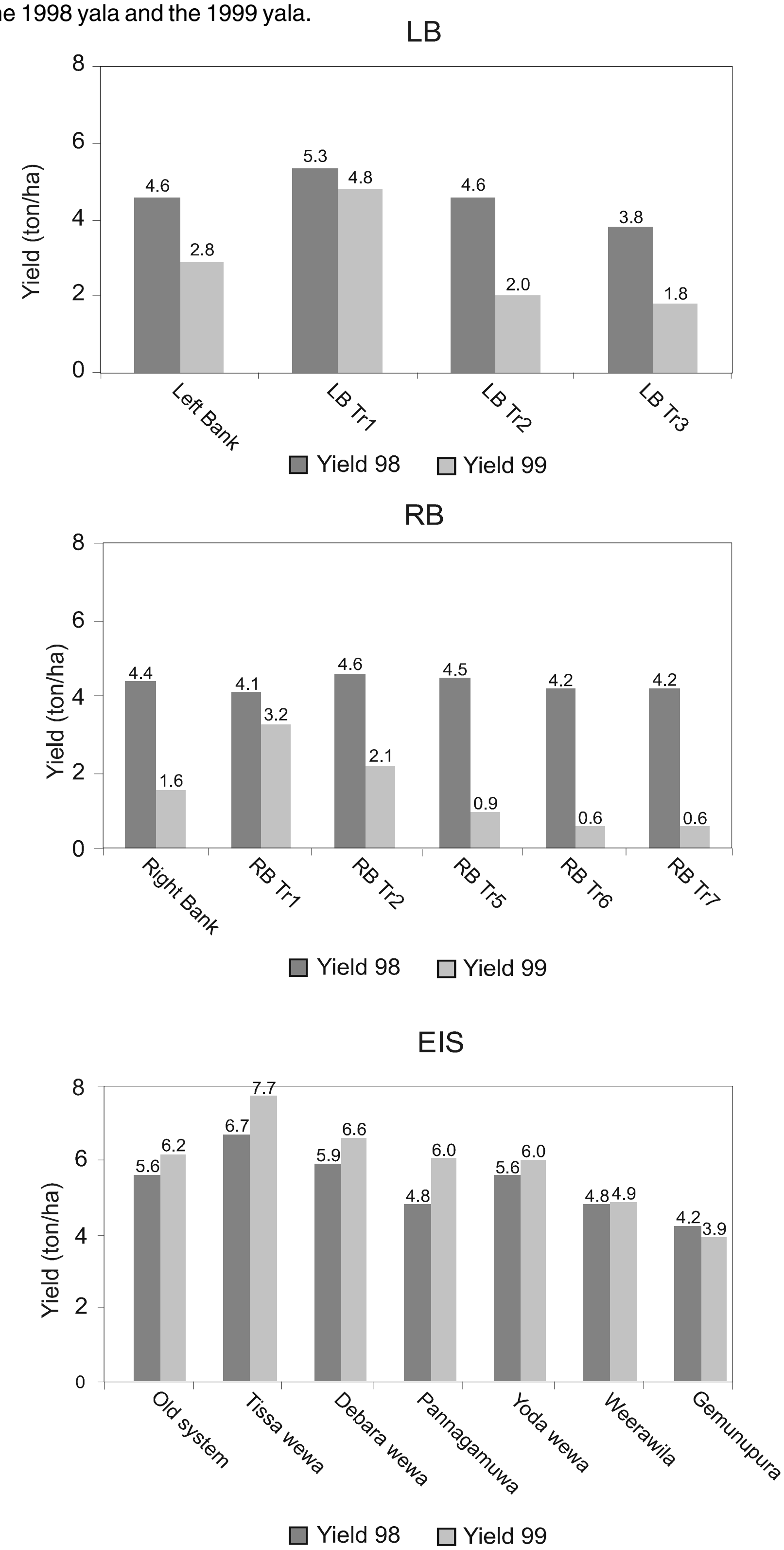
All farmers whose 1999 yields are in the first quartile (less than 1.35 tons/ha) have reported significantly higher paddy yields in 1998. Most of the farmers (73%) in this group are from the RB. Only 17 percent of the farmers whose 1999 paddy yields are in the second quartile (between 1.35 and 3.75 tons per ha) have reported higher paddy yields in 1998.

As far as inputs are concerned, the average fertilizer applications in the four quartiles are not significantly different. Indeed it is clear that water-related factors are the main causes for the yield differences in 1999.

A substantial number of farmers whose 1999 yields are in the first quartile have reported water delivery inadequacies in all stages of crop growth. Most of these farmers are in the RB. Only 11 percent of the farmers in this category have reported water adequacies in the BS and only 2 in the FMS.

Besides the uneven yield distribution between the EIS and NIS it is clear from figures 8 and 9 that there is a head-tail problem between the tracts in the NIS. In the LB the yields of tract 1 and tract 3 are 4.8 tons/ha and 1.8 tons/ha, respectively. In the RB the yields are even lower: RB tract 1 with 3.2 tons/ha and tract 7 with 0.6 tons/ha. The head-tail problem is mainly due to water inadequacy. Figure 9 also brings out the inequity in yields within a tract indicating that water distribution within a tract is not equitable and head-tail problems prevail.

FIGURE 8.
Paddy yields in the 1998 yala and the 1999 yala.



Note: LB= Left Bank; RB = Right Bank; EIS = Ellegala Irrigation System.

TABLE 9.
Farmers reporting water delivery inadequacies in different yield quartiles.

Factor	1999 Paddy Yields			
	First Quartile (<1.35 tons/ha)	Second Quartile (>1.35 & 3.75 tons/ha)	Third Quartile (>3.75 & 6.0 tons/ha)	Fourth Quartile (>6.0 tons/ha)
Number of farmers –Total	44	42	40	31
LB (%)	23	31	18	3
LB (%)	73	29	15	0
EIS (%)	4	40	67	97
% farmers with 1999 yield > 1998 yield	0	17	70	81
1998 average yield (tons/ha)	4.2	3.9	4.7	8.0
1999 average yield (tons/ha)	0.6	2.6	5.1	9.4
Fertilizer application(kg/ha)	389	427	449	452
% reported adequacy in NS	50	67	92	100
% reported adequacy in TS	20	57	90	94
% reported adequacy in BS	11	54	87	94
% reported adequacy in FMS	2	36	75	81

Note: NS=Nursery stage; TS=Tillering stage; BS=Booting stage; FMS = Flowering and milking stage.

Yield Versus Water Inadequacy

The link between water inadequacies at different stages and lower crop yields is investigated here. We use dependent variable, 1999 paddy yield (log transform), in a regression analysis to estimate the effect of water inadequacies on yield.

Explanatory variables

FERT (fertilizer application per ha) (log transform)

D1 (dummy variables for farmers' perception of water adequacy in the LP, i.e., D1=0, if water delivery is inadequate, and =1, if delivery is adequate)

D2 (dummy variables for farmers' perception of water adequacy in the NS)

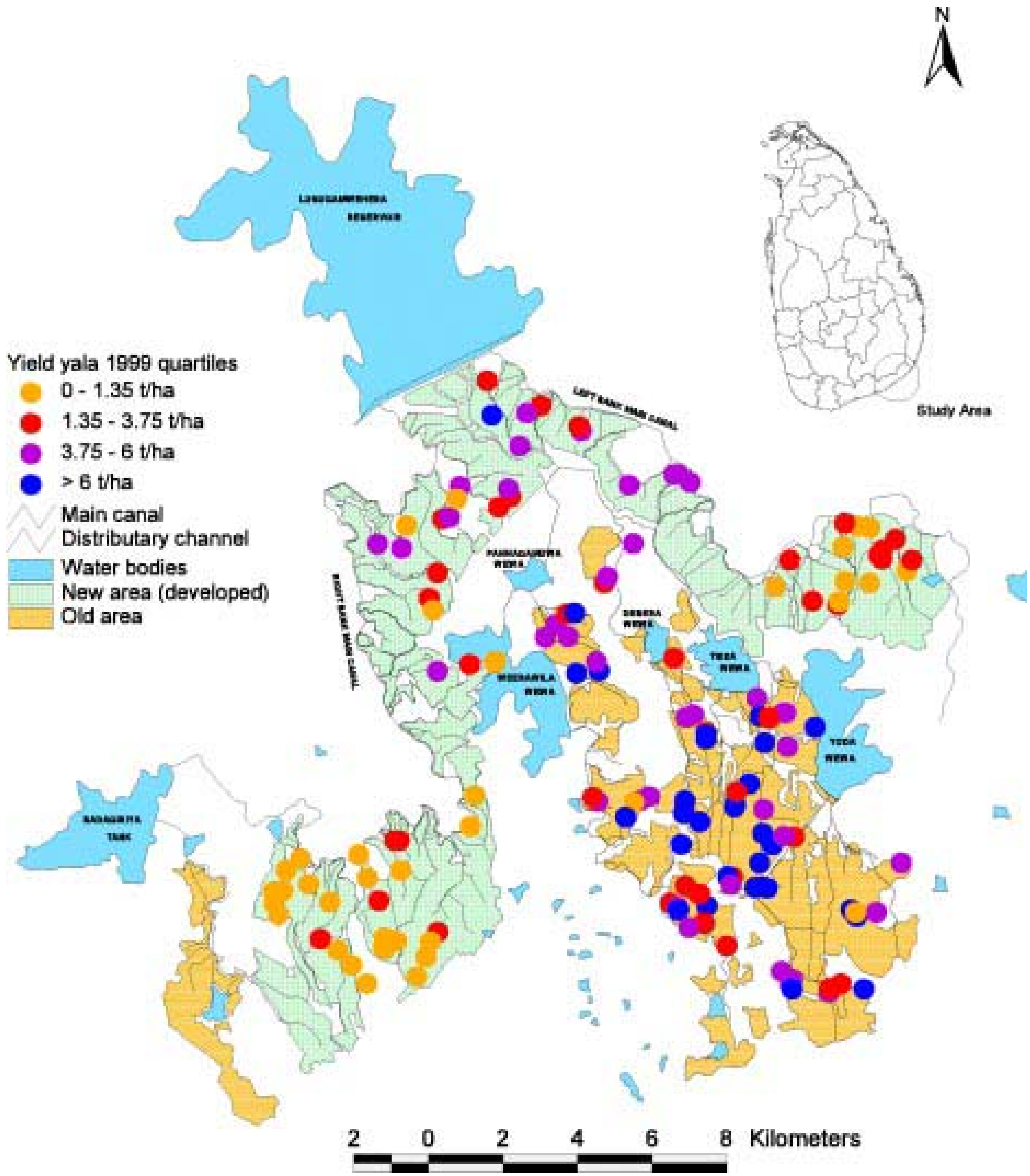
D3 (dummy variables for farmers' perception of water adequacy in the TS)

D4 (dummy variables for farmers' perception of water adequacy in the BS)

D5 (dummy variables for farmers' perception of water adequacy in the FMS)

Farmers who report water delivery inadequacies in an earlier stage have a higher probability in reporting inadequacies in the subsequent stages. Therefore, farmers' perceptions on water adequacy at different stages are highly correlated. To overcome the multicollinearity problem due to high correlation in the last five explanatory variables, we create two new variables. These are the first two principal components of the five dummy variables. These are linear combinations of the

FIGURE 9.
Spatial distribution of yield in the 1999 yala: Kirindi Oya irrigation and settlement project.



five dummy variables and explain 80 percent of their variation. The factor scores of the linear combinations are given in table 10.

TABLE 10.
Factor scores of the first two principal components.

Variable[1]	First Principal Component (PR1)	Second Principal Component (PR2)
D1 (LP)	0.442	0.835
D2 (NS)	0.766	0.311
D3 (TS)	0.894	-0.143
D4 (BS)	0.899	-0.261
D5 (FMS)	0.821	-0.268

[1]Standardized dummy variables.

The first principal component has small weight for the dummy variable for land preparation stage and large weights for the nursery stage onwards. Most of the farmers reported adequate water supply in the land preparation stage. Therefore, the first principal component explains the effect of adequate water supply from the second stage (nursery) to the last stage (flowering and milking). The second principal component has positive weights for the dummy variables of land preparation and nursery stages and negative weights for the tillering, booting and flowering/milking stages. This can be interpreted as the effect due to adequate water supply in the land preparation and nursery stages but with inadequate water supply in the last three stages.

The estimated regression equation is given below:

$$\underset{(0.827)}{\text{Log (yield)} = 1.142} + \underset{(0.137)}{0.004} \log(\text{FERT}) + \underset{(0.045)}{0.475^{*}}\,\text{PR1} - \underset{(0.045)}{0.083^{**}}\,\text{PR2}$$

The numbers within parentheses are the standard errors of the estimated coefficients. The superscript asterisk, * and double asterisks, ** indicate that the coefficients are significantly different from zero at 5 percent and 10 percent significant levels, respectively.

Nonsignificance of fertilizer variable in increasing yield is indicated by marginal increase in yield with respect to unit fertilizer increase. In fact, all systems in KOISP applied more than 390 kg/ha during the 1999 yala.

The significance of PR1 indicates the positive influence of water adequacy of all four stages of the crop growth on crop yield. The significant coefficient of PR2 indicates the negative influence of water inadequacies in the last three stages (TS, BS and FMS) of crop growth on crop yield.

Conclusions

The Kirindi Oya catchment has undergone a rapid transformation since the Lunugamwehera reservoir started operations in 1986. Large-scale migration of settlers to the upstream catchment after 1986 resulted in perceptible land-use changes. Estimated average annual flow into the reservoir shows a decreasing trend over time. The de-seasonalized reservoir inflow after filtering out the rainfall effects has a statistically significant declining trend, which was attributed to increased water use in the upstream catchment. The inflow has been declining slowly, which suggests that it is a major problem only in low rainfall months with little or no inflow entering the reservoir. This situation occurred in the 1992 yala and the 1999 yala.

The progressive decrease of reservoir inflow is an indication of the ongoing upstream development and use of water, which need to be arrested to sustain agriculture in the already developed KOISP. In addition, interannual and intra-annual variation of rainfall in the command area of KOISP is so high as to make seasonal planning unreliable.

Besides the decreasing trend of reservoir inflow and variability of rainfall, another important change has taken place, which makes the Kirindi Oya system even more vulnerable to drought. Farmers have become accustomed to growing paddy during both maha and yala. The practice of growing paddy in yala leaves very little water in the reservoir to start the maha cultivations in time and to the full extent, and it is a threat to the long-term performance of the system.

The 1992 yala was a season of complete crop failure except for the Wirawila tank command. The main reasons for the crop failure were the planting of paddy in the whole EIS area despite the ID's warning. This was confounded by the lower-than-expected reservoir inflow during the season.

The 1992 yala taught important lessons to the EIS farmers. They learnt a great deal about reservoir operations and most EIS farmers have now understood the significance of the MOL of the reservoir for seasonal water allocations. The EIS farmers learnt it was not wise to disregard the ID's advice. The 1992 yala event brings out the importance of rapport, understanding and trust among farmers and agencies managing the system for making a successful season.

The water availability in the reservoir at the beginning of the 1999 yala was low. Despite the decisions of the PMC meeting, the farmers planted the whole area with paddy. To add to the issue of the low water availability at the beginning, the anticipated inflow did not materialize, which created a crisis in water inadequacy for the 1999 yala.

The ID also learnt from the 1999 yala how to manage a system in a water crisis and the ID is now careful in estimating the yala inflow. It is argued that the yala inflow in water-scarce years should not be taken into account for planning the yala crops and the cropping pattern; instead it should be used as a reserve storage for starting the following maha cultivations in time.

The farmers learned from the 1999 yala season to be more disciplined in water use due to higher management efforts of the DCO leaders and field-channel representatives. They also became aware of the value of the reuse of drainage water, which was earlier considered unsuitable for irrigation.

Even with low water supply farmers in the EIS with clayey and clay-loam soils recorded higher yields than in normal years. Further investigation is needed to determine the exact reason for this increase in yield.

According to the ID, the successful completion of the 1999 yala was due to the changed operation of the system, the cooperation received from the DCO leaders, FO representatives and lower-level ID field staff, and due to the ID's large management effort in coordinating the activities of the various stakeholders.

The average yield in the 1999 yala was significantly lower than that in the 1998 yala, with a substantial variation in the 1999 yala yield. Most farmers producing high-yielding varieties in 1998 have obtained even higher yields in the 1999 yala, the majority of them located in the EIS. All farmers with the lowest yields in 1999 have reported significantly higher yields in 1998, the majority located in the RB. Clearly, the water-related factors are the main causes for the yield differences in the 1999 yala, since inputs, such as fertilizer applications, are not significantly different. Also farmers with low yields have reported water delivery inadequacies in all stages of crop growth.

Besides the uneven yield distribution between the EIS and NIS there is a head-tail problem between and within the tracts in the NIS, which is mainly due to water shortage, indicating that water distribution between and within tracts is also not equitable and that head-tail problems prevail.

The evaluation of water distribution practices and the resulting consequences in the 1999 yala is a typical example, which contributes to our knowledge of how to manage an irrigation system in the case of unexpected water shortage. The experience teaches how to manage the system, especially to assure that adequate water is available during the critical stages of the crop-growth period to prevent drastic yield reduction.

While the ID claims that its water distribution strategy caused the crop to mature, it could not rectify the head-tail inequity. The questions are: how should we operate the system to reduce the gaps in yield and what should be the institutional arrangements needed to narrow this gap? Further studies are needed to reduce spatial yield variability, including the necessary institutional arrangements.

The agency managing the KOISP has come a long way in introducing changes and making the system operation acceptable to farmers; however, it has yet to develop an operational plan that will maximize the production of the system. It is recommended that some of these successful innovations be tried out in other irrigation systems with similar hydrologic settings.

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